Roadway Maintenance Manual

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This manual includes information from many technical journals, handbooks, and other resources, including but not limited to:

- Denali Park Road Routine Maintenance, Repair and Operating Standards
- U.S. Environmental Protection Agency, Gravel Roads: Maintenance and Design Manual
- FHWA, Pavement Preservation Checklist Series
- MDOT, Surface Maintenance, Maintenance Performance Guide.

Any errors, omissions, or inaccuracies in this manual should be reported to:

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The manual is intended to be a guide and is not intended to cover every situation or circumstance. General practices and principles provided herein may need to be modified to address the needs and challenges specific to a given facility or situation.

Disclaimer

The contents of this guide reflect a combination of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the NPS or the FHWA. This guide is a reference only document and does not constitute a standard, specification or regulation. Users of this manual do so with the understanding and agreement that they assume full responsibility for the outcome when following the recommended practices herein.

1 INTRODUCTION

Purpose

This Roadway Maintenance Manual was developed to document and describe routine procedures recommended as best practices for maintenance of NPS roadways.

The goal of the document is:

- To focus on routine maintenance practices that could be performed by NPS personnel
- To provide readily available information to the NPS park-level facility maintenance section (chief of maintenance, roads supervisor, and maintenance worker) at individual parks regarding their roadway maintenance needs
- To provide a systematic guide for maintaining new and existing roadways for the NPS
- To be useful to park-level maintenance road managers and supervisors looking for ways to maintain the serviceability of the existing roadway network.

Introduction

Throughout the life of a paved or unpaved road there are simple maintenance activities that are necessary to realize the road's full service life. These activities are simple maintenance that should be performed periodically as recommended in this manual. The objective of these activities is to delay or reduce deterioration of roads or road elements. In doing so, the NPS can maintain its assets at the lowest cost over the life of the roads.

This manual also identifies repair activities that may be required in order to return a damaged road to serviceable condition. Often these repair activities will both restore serviceability and prevent further deterioration.

Historically it has been found that a strong preventive maintenance effort is a cost effective approach. Preservation activities cost much less than major reconstruction or replacement activities. Delaying or forgoing preservation treatments will result in worsening condition for roads and eventually accelerate the need for roads to be rehabilitated or replaced.

From a holistic viewpoint, simple maintenance can eliminate cascading sequences of distressful events. For example, pothole repair can prevent widening of a disturbed road surface. Drainage maintenance can prevent damage or failure of a road.

NOTE: Each park's mission and road network is different. One method which may be appropriate for some park roads may not apply to other park roads where other methods may be required. Individual parks will use their own resourcefulness and experience, in conjunction with this manual, to optimize their maintenance strategies and practices.

2 TROUBLESHOOTING GUIDE

This troubleshooting guide is intended to be a quick reference to help maintenance professionals understand some common problems on park roads and direct them to the relevant sections of this manual.

2.1 Road Surface Problems

Problem: Tire rutting on soft unpaved roads
Possible Causes:

1. Poor road base material. Road base needs to be reconstructed with suitable materials, or consider using geotextiles.
2. Road is too low and the base is in the water table. Raise road grade.
3. Poorly drained native soils that may be unsuitable as base for aggregate surfacing. Consider using geotextiles, or increase depth of aggregate.
4. Insufficient shoulder drainage. Ditches should be graded deep enough to allow subsurface water to drain out of the road base. If a roadside ditch is in a groundwater seep area, consider underdrain at those locations.

Problem: Muddy or slick road surface on unpaved roads
Possible Causes:

1. Road surface may contain too many fines. Granular surface material needs to be added or blended with existing surface using appropriate grading equipment.
2. Insufficient crown (super elevation), which may allow water to collect on the road surface. Grade road to provide adequate drainage.

Problem: Longitudinal (lengthwise) erosion of the road surface on unpaved roads
Possible Causes:

1. Flat or reverse-crown. A positive crown (super-elevation) is needed to shed water laterally off the outer edge(s) of the road surface.
2. Small ridge of soil or grass growth along the outer edge of the road is preventing water from draining off the road surface. Edge needs to be graded to remove this ridge.
3. Water is traveling in a wheel rut. Road needs to be regraded. This problem often results from soft roads.
4. Roadside ditch is not large enough and overflows onto road surface. Install ditch relief culverts or ditch turnouts to prevent overflowing. If this is not possible, ditches should be regarded to provide sufficient capacity.
5. Snow banks may be preventing water from draining off the road in the early spring. Plow snow wide enough to allow the drainage to leave the roadway. Be careful not to focus the flow along the edge of pavement, or into erodible shoulder material.

Problem: Washboarding on unpaved roads
Possible Causes: Poor road surface materials. This most likely results from a lack of fine material or inadequate plasticity in the fine material. Check the gradation and classification of the road material, and adjust as necessary. A grader may be used to smooth the washboarding and to mix the road materials. Alternative road surface materials may need to be mixed with existing materials in certain situations.

Problem: Potholes on gravel roads
Possible Causes: Potholes often result from road sections on poorly drained soils or from insufficient crown. They can also result from improperly constructed asphalt pavement. Determine the cause and correct appropriately. Temporary repairs can be made with cold mix, or proprietary patching mixes, depending on local sources and available supplies.

Problem: Too much loose gravel on gravel roads
Possible Causes: Poor road surface material that lacks fines or lacks plasticity in those fines. Consider the addition of fines or plastic fines, as appropriate.

Problem: Dust on unpaved roads
Possible Causes: Poor road surface materials. Apply new road surface material with the proper soil gradations (see Table 2), or use approved dust suppression agents. The FHWA, through the Coordinated Technology Implementation Program, has evaluated numerous dust palliatives and new products are constantly being developed. Consult with the FHWA or with the Denver Service Center for guidance on available, effective dust suppression products.

2.2 Ditch Problems

Problem: Sides of ditches are eroding or slumping
Possible Causes:

1. Side slopes need to be stabilized to protect against erosion.
2. Side slopes are too steep and need to be lessened by laying them back where possible.
3. Groundwater seeps are present. One solution may be to armor ditch side slopes with riprap, or relieve the subsurface water with underdrains or French-drains.

Problem: Bottom of ditch is eroding or silting in
Possible Causes:

1. Ditch may need maintenance to remove debris or accumulated road sand or sediments.
2. Slope of ditch may be too steep and causing erosive flow velocity. The addition of vegetative protection, erosion control blankets, riprap, check dams, and/or ditch turnouts can reduce or eliminate erosion due to high velocities and steep grades.
3. Ditch capacity is too small to handle the volume of water flowing through it. Consider installing ditch turnouts or periodic cross-drains to reduce the flow rate in the ditch. If these remedies are not possible, consider regrading the ditch to provide sufficient capacity.
4. Bottom of ditch is too narrow (V-shaped) and needs to be widened (parabolic shaped).

2.3 Culvert Problems

Problem: Water overflows at culvert inlet
Possible Causes:

1. Culvert has been crushed and needs to be replaced.
2. Culvert is plugged with sediment and debris. Inspect on a regular basis and maintain (flush) as required. If it is full of sediment, check uphill road and ditches to see if areas upstream of culvert are eroding. If upstream erosion is found, repair as necessary.
3. Culvert is undersized. Culverts need to be sized appropriately in relation to the drainage area. Ditch relief culverts and/or ditch turnouts may be needed upstream to reduce flow volume at the culvert. Minimum recommended culvert diameter for maintenance purposes is 24" across roadways and 18" across driveways.

Problem: Culvert fills with dirt and debris
Possible Causes:

1. Culvert inlet basin full or not deep enough.
2. There is upstream erosion that needs to be addressed.
3. Culvert placed with too little or no slope.
4. Culvert outlet is clogged and in need of cleaning.

Problem: Crushed culvert
Possible Causes:

1. Culvert has been weakened by rust and needs replacement. .
2. Improper installation. Top of culvert should be at least one foot below finish grade and even deeper if heavy construction loads are anticipated.
3. Improper compaction of surrounding backfill can damage a culvert (compact soil in specified lifts and with specified materials). Oversize material (rocks, etc.) can damage the culvert if placed and compacted too close to the culvert walls.

Problem: Voids in roadway above the culvert
Possible Causes:

1. Culvert has rusted through, allowing water to seep around the pipe. Replace culvert.
2. Improper installation. Backfill may not have been compacted sufficiently, which allows material to settle and/or water to seep around and along the culvert.
3. Water is seeping alongside the culvert. Install inlet anti-seep collar, or recompact material around inlet end sections or headwalls.

Problem: Culvert is eroding around the ends
Possible Causes:

1. Water is seeping alongside the culvert. Install inlet anti-seep collar or recompact material around the end section or headwall.
2. Culvert is too short and does not have proper protection/backfill on the side slopes.
3. Insufficient armoring of culvert ends with riprap or headwalls. Outlet of the culvert should also be protected with riprap, aprons, gabion baskets, or other devices depending on the site conditions.

3 WORK SITE SAFETY

The NPS has a continuing concern about the health and safety of its employees and others who spend time in the parks—whether as visitors, volunteers, contractors, concession employees, or in any other capacity. Those who participate in work or recreational activities in the parks are always, to some extent, exposed to the risk of accident, injury, or illness. In recognizing this, the NPS is committed to reducing these risks and the associated pain, suffering, and financial expense.

The safety and health of the visiting public, our employees, contractors, and volunteers is a core value of the NPS. Therefore, it is the NPS policy to provide for a safe and healthful place of employment and to protect federal and private property from accidental damage or loss associated with NPS operations. To implement this policy, NPS employees will comply with Director's Orders #50A and #50B.

Some of the requirements of work site safety for employees include:

- Promoting and enforcing safe work practices and integrating safety and health into every operation and activity
- Identifying recognizable threats to employee safety and health and to the protection of property, by applying nationally accepted codes, standards, engineering principles, and the guidance contained in the NPS Director's Order #50B. Where practicable and not detrimental to the NPS mission to avoid impairing park resources, known hazards should be considered for reduction or removal. If a road hazard cannot be eliminated, efforts should be made to provide for peoples' safety and health through other controls, including closures, guarding, signing, and law enforcement and employee education
- Inspect every NPS workplace, as outlined in Reference Manual #50B, section 4, and correct deficiencies in priority order to meet all applicable standards
- Provide employees with the supervision, knowledge, equipment, and skills necessary to safely perform their assigned tasks.

These are just a few of the requirements set forth by the NPS Director's Order #50B and Reference Manual #50B, Occupational Safety and Health Program. In conjunction with work related to these guidelines, review Director's Order #50B and Reference Manual #50B for applicable requirements.

4 ROUTINE ROAD MAINTENANCE ACTIVITIES

4.1 Roadside Mowing

The ultimate goal of roadside vegetation management is to produce and maintain healthy, low-maintenance, self-sustaining roadsides by encouraging beneficial vegetation. Proper roadside vegetation management should be based on the current vegetation type and condition of the roadside plant community.

The roadside is comprised of an active zone, which is typically the area 15 feet away from and parallel to the paved shoulder, and a passive zone, which is the remainder of the right-of-way width. The passive zone should not be mowed unless it is a component of a predetermined management issue, such as snow drifting areas, sight distance, aesthetic issues in urban areas, a component of weed control plans, or some component of an individual park's mission.

Mechanical mowing may be used to:

- Maintain safe sight distances and visibility for signs
- Control noxious and nuisance weeds
- Reduce the potential for snow drifting
- Improve aesthetics
- Reduce fire hazard due to vehicular traffic.

Mowing should be performed only when necessary, and as part of a roadside management plan. Mowing should be limited during the growing season if possible. Mowing after grasses reach dormancy (usually after July 15) will encourage the development of healthy, low-maintenance,

self-sustaining roadsides. Mowing should be timed to support and not conflict with noxious weed control plans and forage removal/haying operations.

4.2 Vegetation Management (Horizontal/Vertical Clearance for Roadside Clearing)

This section addresses the management of vegetation along park roads to improve and maintain horizontal and vertical sight distance.

While clearing line of sight for motorists is an obvious safety consideration, it also allows park facility managers to observe a greater portion of their roadway assets during day-to-day operations and improves their ability to recognize maintenance issues as they occur.

Elements which define the sight distance requirements for the roadway or back slope are:

- Vertical alignment
- Horizontal alignment
- Design speed
- Grade
- Clearance.

4.2.1 General Roadside Maintenance Brushing

The goal of vegetation management along the park road is to maintain safe stopping sight distance and the prevention of physical contact between vegetation and vehicles.

Initial cutting could be performed by crews using chain saws or other hand tool methods to remove coarse, mature and heavy growth vegetation over ¾" stem diameter. Vegetation removal should include cutting all stumps to a height not greater than 4" above the ground level.

As each park's mission allows, all cut material should be removed from the work zone and disposed of in accordance with local park policies and practices. Trees that represent safety hazards should be removed immediately using any available park personnel and equipment and traffic should be directed away from the hazard, if immediately threatening the roadway.

4.2.2 Alignment

Horizontal alignment and grade should be maintained as originally designed and constructed, if designed and constructed according to appropriate standards. Abrupt changes in vertical alignment resulting from erosion, settlement, or uplifting should be repaired to the original alignment, following a parabolic curve which retains a smooth grade transition throughout.

Where slope failures necessitate horizontal realignment, such realignment should be constructed using horizontal and vertical curves that conform to the appropriate design speed and consider the local site topography.

4.3 Shoulder and Drainage Maintenance

This section addresses the cleaning, repair, installation and maintenance of drainage systems and their components. Drainage maintenance is one of the most important functions which should be performed to ensure a long-lasting roadway. Neglecting drainage maintenance almost always results in moderate road distress and can result in catastrophic failure (e.g., loss of road surface or entire road structure).

Routine maintenance should occur annually to prevent build-up of sediments, debris, and encroaching vegetation as well as to provide site specific inspections. Corrective maintenance should be focused at sites where the existing drainage system or system component has ceased to function adequately or where installations of new culverts or drainage systems are necessary to protect the roadway and the surrounding terrain.

4.3.1 Existing Drainage Structure Cleaning

As illustrated and described in Section 5, water intrusion into a pavement will cause the pavement and its base course to weaken and fail. For paved roads, crack sealing and filling prevents water penetrating the pavement section from the top (see Section 5). Drainage structures direct flowing water away or from or under roadways, preventing water from eroding or saturating the roadway.

Routine maintenance should occur annually to prevent build-up of sediments, debris, and encroaching vegetation as well as to provide site specific inspections.

When the road is exposed to water:

1. The road bed can be compromised as discussed in Section 5, resulting in loss of fines (small soil particles) from the base course, eventually leading to localized pavement failure (potholes).

2. The edges of the road can be undermined by flowing water. This will lead to the loss of shoulders or roadway edges, and in extreme cases, it results in the entire loss of the travel lanes.

To prevent water-related damage, maintain the capacities and capabilities of existing drainage facilities and structures by keeping them free of debris and by repairing minor erosion as soon as it is discovered. Timely and effective maintenance of culverts and drainage facilities can prevent damage that is typically much more costly than a well planned and executed maintenance program. Catastrophic water-related damage to roadway sections may also result in unsafe driving conditions.

General checklist and precautions:

1. Safety should always be the first consideration: If a culvert is large enough to allow a person to enter it, that person should wear proper safety gear and protective clothing. Confined space work precautions must be considered and observed. Beware of sharp objects, unstable debris, and animals.
2. Debris should be isolated before attempting to remove it. Ensure that it is not interlocked with the culvert or other debris. Prevent the debris from suddenly becoming loose and potentially injuring a worker.
3. Use the appropriate hand tools or power tools, depending on the debris being removed.
4. Hand and power winches may be useful for removing larger debris pieces.
5. Ensure that the debris is not attached to or interlocked with the drainage structure when using a power or hand winch or other tools for removal to prevent damage to the drainage structure.

4.3.2 Ditches

One of the most common drainage structures is the roadside ditch. If the ditch becomes obstructed by eroded soil or debris, it must be cleaned. Sometimes this can be a major operation requiring loaders, excavators, motor graders, trucks, or other mechanized equipment. Sometimes workers with hand tools can maintain a ditch (the individual park's circumstances will determine the best approach). Under the right conditions a skilled operator and a motor grader can be quite effective in maintaining and restoring ditch drainage.

Roads should be built well above any potential water sources, whether flowing, standing, or subsurface. Unfortunately, this is not always an option due to existing road structures and the local topography. Therefore, installing good ditches, including adequate ditch relief and cross-drains, is critical to the function and longevity of the road. Properly designed and constructed ditches serve a number of essential purposes:

- They collect runoff from the road surface as well as surface flows from adjacent drainages and carry it away from the road
- When constructed with properly designed ditch relief features, they keep pollution from reaching sensitive water resources
- Ditches can help drain water from road base material to reduce frost heaving and to reduce pavement damage and other problems associated with weakened and saturated sub-base and sub-grade layers.

Proper ditch construction involves careful consideration of many factors, including watershed size, anticipated rain intensity and duration, degree of slope, width of right-of-way, ditch size and shape, and native soil type. It's always advisable to have an experienced and qualified person design the ditch.

Ditches should be regularly inspected and maintained.

- It is critical to keep ditches free of obstructions and sediment to allow water to flow as designed.
- Accumulation of leaves and debris can decrease the capacity of a ditch and restrict the ability to establish and maintain a vegetative cover. Heavy accumulations of leaves and other debris should be cleaned from ditches as soon as practicable after they have been deposited.
- For major ditch maintenance, a truck with appropriate loading equipment may be required to haul off the debris. If appropriate, considering natural and/or cultural resource impacts and available equipment, consider using a machine with a hydraulically adjustable tilt (called a grading or ditching) bucket. This allows the operator to shape the ditch much more evenly and efficiently.
- Water should be routed away from the road and turned out frequently, so that it can be discharged into a stable vegetated area in low volumes and velocities. This practice allows the water to filter and absorb into the surrounding vegetation and prevents large volumes of water from escaping the ditch and eroding the road edges.

4.4 Winter Operations

Snow Removal—A Special Note

The goal of controlling and removal of snow and ice is to provide safe access within the park during winter months and is therefore a facility operations task rather than a maintenance one. Two important notes about snow removal and road condition:

- Removing snow from a road exposes the road to freeze-thaw cycles, whereas leaving a road encased in snow and ice protects it from those cycles. Pavements are damaged due to freeze thaw. Sealing the paved surface can mitigate but not eliminate this effect
- Snow and ice removal can physically damage a road surface (paved or unpaved).

4.4.1 Spring Road Opening

The appropriate date for beginning spring road opening operations is typically governed by park policy based on input from many sources, including the facility manager or roads foreman. It is ultimately the superintendent's decision, and the policy may vary from park to park. These guidelines are not intended to, and should not, contradict or otherwise interfere with or impact official park policies or procedures related to snow removal.

Spring snow removal procedures, in addition to the opening of the road for visitors and park staff, should accomplish the following:

- Provide for the drainage of snowmelt, preventing damage to the roadway from runoff
- Prevent snow and trapped melt water from remaining in the ditches to avoid saturating the road base and sub-grade (which if allowed will result in weakening of the road sub-grade, base, surface, and shoulders)
- Maintain an adequate clear zone for storing subsequent spring snow
- Ensure that the snow removal operations support whatever the local park policies are for the timing of road openings.

Care should be taken when crossing park bridges with tracked equipment, and adequate padding should be used during such crossings to prevent damage to these structures.

4.5 Roadside Vegetation

Routine maintenance of the road shoulder is important for retention of roadway strength and integrity. Objectives are to remove oversize brush on the outermost part of the road shoulders and down slopes so that the shoulders can be observed and maintenance needs can be more easily identified.

4.5.1 Road Shoulder/Fill Slope/Ditch Line Maintenance Brushing

Brushing boundaries should typically not exceed beyond the edge of the road shoulder or the top of the back slope unless approved by the park resource and compliance staff.

To maintain a more natural look and to soften the appearance of the road corridor from a distance, it may be desirable to leave brush with an undulating random edge from the toe of the slope. When possible, combine brushing and routine shoulder maintenance so the finished product appears seamless and blends with local surrounding vegetation.

4.5.2 Vista/View Shed Maintenance Brushing (Designated Viewing Pullouts)

Routine brushing activity (removing and shaping roadside vegetation) is important to preserve and maintain existing vistas and view sheds along the park roads. Established pullouts, vistas, and stopping points along the park road corridor should be brushed, as needed, to preserve intended views for the visitor.

Why Brushing?

Brushing crews should put extra effort into making the transition from road to wilderness as seamless as possible. The goal is to leave the visitor with the impression that they are observing an unaltered landscape.

Above the travel way, trees should be limbed to adequate levels to provide clearance for vehicles, with appropriate consideration for oversize vehicles and to maintain adequate sight distance.

Brushing Considerations

In designated vista locations, vegetation that has grown unequally or dissimilar in size to local species due to enhanced growing conditions should be removed. Vegetation similar in size and type to local species should be retained to soften the transition from roadway to wilderness. Oversize brush within these limits should be removed as needed to bring about this transition and enhance distant panoramas.

4.6 General Roadway Maintenance

This section addresses the maintenance and repair of signs and markers along the park road. The goal is to maintain appropriate traffic control, safety and information markings, and signage that meet the requirements of the Manual on Uniform Traffic Control Devices (MUTCD) and the National Park Service Sign Manual (NPSSM).

The MUTCD as supplemented by the NPSSM contains detailed guidance regarding design, location, and application of road signs and markings.

4.6.1 Pavement Edge Drop Off

Edge failures are generally caused by traffic loading at the edge of the pavement in conjunction with water-related issues (poor subsurface drainage or inadequate surface drainage). Edge failures will usually migrate into the traveled way if not repaired in a timely manner.

Pavement edge drop-offs may occur as a result of construction or maintenance work. When not properly addressed, drop-offs may lead to, or contribute to, the severity of accidents. An edge drop of more than 2" and edges that are not tapered or ramped (45° or flatter) pose a significant safety hazard.

This safety problem is minimized where the pavement edge drop-off does not exceed 2" in height or the face has a 45° or flatter slope.

4.6.2 Pavement Markings

Pavement markings should comply with the MUTCD. Paint should be re-applied when the existing painted surface shows a loss of visibility and/or retro reflectivity. This will vary with traffic volume, type of weather/climate, and snow removal activities. A rule of thumb might be repainting every two years on surfaces that are plowed throughout the winter and every five

years on all other surfaces. The condition of the pavement markings should be the primary factor determining how frequently roads are restriped. Check with the FHWA or the Denver Service Center for any questions regarding the type, application rate, or other details when reapplying pavement markings.

5 SURFACE MAINTENANCE - ASPHALT

This section covers methods and procedures for asphalt surface maintenance and repair, including crack sealing, pothole patching and repair, and traffic loop maintenance.

These surface maintenance activities are needed when the following are observed:

- Longitudinal or transverse cracking: when cracks show gap widths sufficient to accept application of sealant (approximately 1/8"), or when the cracks extend completely through the asphalt pavement section depth.
- Alligator cracking: cracking that forms a network of small asphalt blocks with a pattern similar to alligator skin. (Note that alligator cracking is usually a sign of sub-grade failure. Patching and filling is only a temporary measure for this distress).
- Potholing and shoulder un-raveling: where the asphalt concrete appears to be decomposing into aggregate.

When practical, if removed by milling machine, asphalt may be stockpiled and recycled for use as surfacing or repairs for unpaved roads with low volume traffic.

5.1 Crack Sealing and Crack Filling

Crack sealing and filling is the cleaning and filling of random open cracks in pavement surfaces with rubberized sealant in order to prevent further water intrusion. Crack sealing and filling use a rubberized liquid emulsion designed specifically to withstand environmental elements to prevent passage of water to the base or sub-grade and permit pavement joints to contract and expand properly. Crack types include: fatigue cracks, longitudinal cracks, transverse cracks, block cracks, reflective cracks, edge cracks, and slippage cracks.

Note: Crack sealing applies to larger, “working” (i.e., expanding and contracting) cracks. Crack filling applies to non-working cracks. The term crack sealing will be used to describe both in general. The differences between the two are specified below.

General checklist and precautions:

1. Pavement structure and subgrade should be sound. Crack sealing will not be effective if the pavement section or sub-grade shows structural defects (other than the cracks) or other indications of weakness or water/drainage problems.
2. Best results are achieved when cracks are as closed as possible (due to thermal expansion) and when ambient temperature is above 50° F.
3. Sealing should not be performed in the rain or if rain is imminent.
4. Before filling, clean cracks with a hot air lance. Use caution to avoid overheating pavement surfaces.

5. Application should not begin if there is any moisture on the surface or in the crack.
6. Apply sealant heated to the specified application temperature, using the applicator, before the crack cools.
7. 3/8" stone or backer rod may be used as filler for wide cracks.
8. Sand or other approved materials may be used as blotter material to prevent tracking of fresh sealant.
9. Sealant should be reapplied to deeper cracks where sealant has settled or where too little material was applied.
10. Adhesion is checked by pulling up cooled sealant. The sealant should remain stuck to the pavement. Unbounded sealant should be removed and the crack resealed.
11. Allow material to set before opening to traffic.

5.1.1 Crack Sealing

Crack sealing is the placement of materials into working cracks to reduce infiltration of water and incompressible materials. Crack sealing requires thorough crack preparation and often requires the use of specialized materials placed either into or over working cracks (cracks with movements of 2.5-5.0 mm horizontally) to prevent the intrusion of water and incompressible materials. Crack sealing is generally considered to be a longer-term treatment than crack filling.

Due to the moving nature of working cracks, a suitable crack sealant must be capable of:

- Adhering to the walls of the crack
- Elongating to the maximum opening of the crack and recovering to the original dimensions over a range of service temperatures without rupturing or delaminating from crack walls
- Resisting abrasion and damage caused by traffic.

5.1.2 Crack Filling

Crack filling is the placement of materials into nonworking or low movement cracks to reduce infiltration of water and incompressible materials into the crack. Filling typically involves less crack preparation than sealing and performance requirements may be lower for the filler materials. Filling is often considered a short-term treatment to help hold the pavement together between major maintenance operations or until a scheduled rehabilitation activity takes place.

Crack filling is for active or non-active cracks which have been created by ageing of the asphalt binder in the pavement. Such cracks are not completely inactive and require some flexible characteristics. A suitable filler material must be capable of:

- Remaining attached to the walls of the crack
- Possessing some elasticity
- Resisting abrasion and damage caused by traffic.

<u>Recommendations</u>

The first question to be answered is whether crack sealing or crack filling is the appropriate activity. In order to determine whether to seal or fill a crack, it must be established whether the crack is working or non-working and whether the crack undergoes horizontal or vertical movement.

The criteria for deciding whether to seal or fill a crack are listed in Table 1. Cracks may open and close horizontally with temperature and moisture changes and may undergo vertical movements as the result of load applications. The type of crack can provide an indication of whether it is a working crack or not. Working cracks can be transverse or longitudinal to the pavement but are most often transverse. Working cracks with limited edge deterioration should be sealed rather than filled.

When the criteria for working cracks is not met, or when cracks are closely spaced and have little movement, crack filling is the less expensive option (FHWA, 1999).

Table 1. FHWA Criteria for Crack Sealing or Filling (FHWA, 1999)

CRACK CHARACTERISTICS	CRACK TREATMENT ACTIVITY	
	CRACK SEALING	CRACK FILLING
Width	0.12-1" (3-25 mm)	0.12-1" (3-25 mm)
Edge Deterioration	Minimal to None (< 25% of crack length)	Moderate to None (< 50% of crack length)
Annual Horizontal* Movement	≥ 0.12" (3 mm)	< 0.12" (3 mm)
Type of Crack – Please see Appendix A	• Transverse Thermal Cracks • Transverse Reflective Cracks • Longitudinal Reflective Cracks • Longitudinal Cold Joint Cracks	• Longitudinal Reflective Cracks • Longitudinal Cold Joint Cracks • Longitudinal Edge Cracks • Distantly Spaced Block Cracks
* Annual horizontal movement is calculated by multiplying the distance between cracks times the typical annual temperature difference times the coefficient of expansion (0.0001in/in/ºC).		

5.2 Pothole Patching & Edge Failures

NOTE: **Consult your Regional Coordinator or engineer for subsequent pavement preservation treatments that can/will be applied following patching.**

The primary methods of patching include the replacement of materials that have been lost due to localized pavement distress or disintegration, the complete removal (dig out) and replacement of continuous segments of failed pavement, or the application of a thin layer of hot-mix asphalt (HMA) material over segments of pavement that exhibit more surface-related distress/distortion. Once patched, the distressed area is repaired or strengthened so that it can carry a significant traffic level with improved performance and lower rates of deterioration.

Parks may wish to perform localized patching to restore ride quality and prepare for pavement preservation treatments.

Patching may be a temporary, semi-permanent, or permanent treatment. The appropriate method to be used depends on the traffic level; the time of the year during which the repair is carried out; the time until scheduled rehabilitation; and the availability of equipment, personnel, and resources.

Patching, one of the most expensive of the maintenance procedures for HMA pavements, is often done in preparation for other forms of corrective maintenance, pavement preservation, or pre-treatment prior to an overlay. Patching restores the pavement surface to a state where other preservation treatments can be used with a good chance of success.

Patching is best carried out during clear moderate weather. However, emergency repairs may require patching to be performed during poor winter weather conditions. In these instances, the durability of the patch is likely to be poor, and the patch should be considered to be temporary. Accordingly, it is a good strategy to plan for a more semi-permanent repair of these areas when more conducive weather conditions prevail.

This topic is divided into pothole patching, material dig out and replacement, edge repair, and surface reinstatement.

5.2.1 Pothole Patching

Patching is a process in which the material in a highly distressed area is removed, the resulting hole prepared for patching, and new material applied to replace the former distressed material, sometimes with additional material added to cover up the distressed area. Merely filling a hole will not prevent the development of distress adjacent to or within the patch in many instances. Maximum performance is achieved when the boundaries of the distressed area are appropriately marked and cut, the failed material is removed, the remaining (underlying) material is recompacted, the hole is properly prepared, and new material is added and compacted to a level similar to that for a new pavement.

The primary methods used to perform pothole patching are:

- Temporary
- Semi-permanent
- Injection patching.

The primary materials used for pothole patching are:

- HMA—commonly preferred
- Cold-mix asphalt—recommended as a temporary fix only
- Aggregate/asphalt emulsion combinations (i.e., injection patching, which requires specialized expertise and equipment)
- Special patching mixtures.

Potholes are created by breakdown or disintegration of the pavement. This may be associated with poorly compacted material, subsurface water issues, raveling, cracking, base failure or aging of the pavement. Potholes often appear after rain or during thaw periods when pavements are weaker and the subgrade is wet or saturated. The general process for how a pothole develops is as follows:

- Raveling, stripping, or cracking occurs in the pavement surface (the pavement surface is compromised—see Section 5.1).
- Water penetrates the surface layers of the pavement, softening the underlying pavement layers and subgrade, which increases the pavement's ability to deflect. Figure 1 illustrates how water can penetrate a pavement.
- Ice formation and heaving (due to entrapped water expanding when freezing) in the pavement occurs in some climatic areas. Figure 2 illustrates heaving due to a freeze-thaw cycle in a cold climate.
- Fines from the underlying pavement and subgrade layers are forced out, reducing overall structural strength and support for the pavement surface. Figure 3 illustrates the resulting cavity when the fines are lost due to migration or pumping.
- The weakened, unsupported pavement fails, leaving a hole. Once a hole is formed, it will continue to grow until it is repaired. Figure 4 illustrates the role traffic plays in enlarging a pothole.

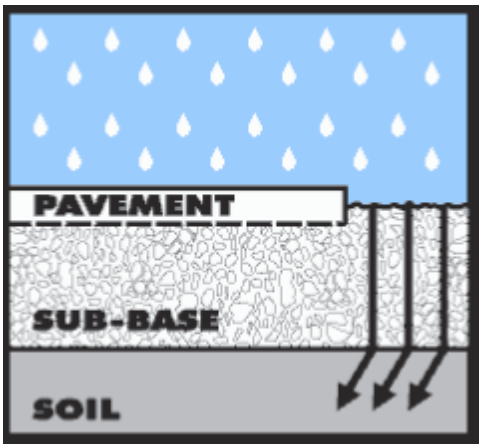

Figure 1. Water Penetration of Pavement

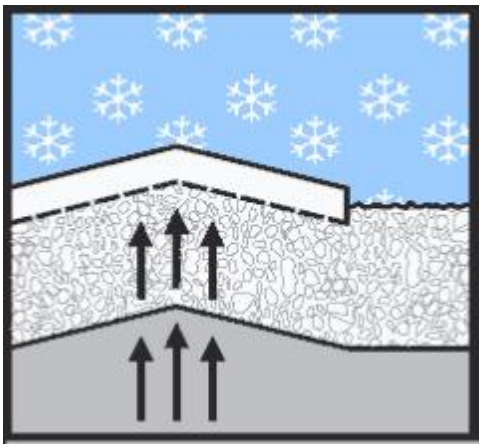

Figure 2. Heaving Effects Caused by the Freeze/Thaw Cycle

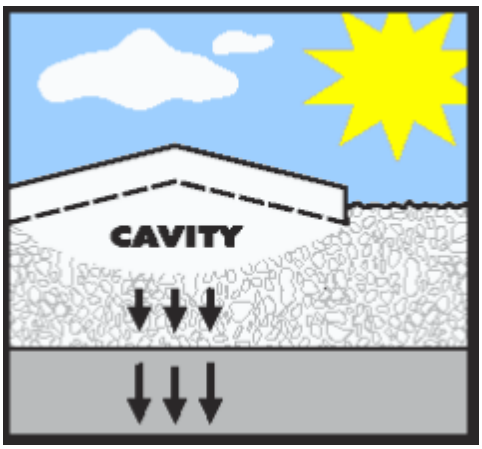

Figure 3. Loss of Fines Results in a Void

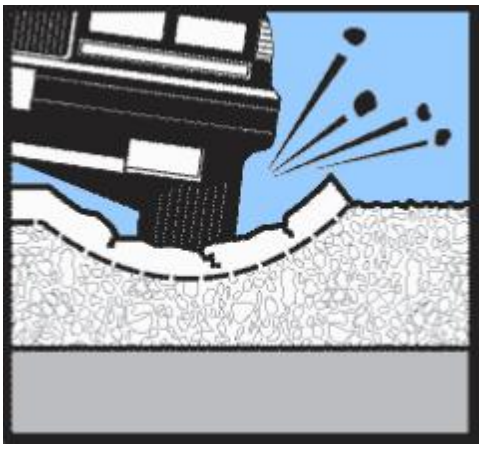

Figure 4. Once Formed, Traffic Enlarges Potholes under the Pavement

Construction Methods for Pothole Patching

Construction procedures for pothole patching vary according to the method and materials selected. There are three primary patching techniques that will be discussed in this manual.

Throw and Roll

The "throw and roll" method is often used for temporary patches. This type of patch will fail under traffic use and adverse weather. This is only appropriate when weather conditions are too poor for a semi-permanent patch to be placed, the road is due to be rehabilitated soon, and/or there is an immediate safety issue that requires a quick, short-term fix. It is the least expensive and least labor-intensive method for patching a pothole and includes the following steps:

- Patching material is placed into the hole, with or without cleaning and/or drying of the hole
- The material is compacted using the maintenance truck tires
- The finished patch should have 1/8" to 1/4" (3 to 6 mm) of crown to help avoid water ponding
- Clean-up is generally low effort or not required.

Figure 5. "Throw and Roll" Method

Semi-Permanent Patches

Semi-permanent patching is considered to be an effective patching method (second only to complete removal and replacement of the failed area). The following steps describe how this form of patching is carried out:

- Mark the boundaries of the distressed area (see Figure 5), taking care to encompass a slightly larger area than that reflected by the distress. The repair boundaries should be as rectangular as possible and take into consideration the dimensions of the equipment that will be used for removal of the old material and compaction of the new material.
- Cut the boundaries of the patch square using either a diamond saw or pneumatic hammer with a spade bit. In the case of the latter, care should be taken not to damage the HMA surface layer in the sound pavement.

- Square up the sides of the hole until the edges of the hole are sound pavement. This step is usually very simple if the boundaries of the repair area were cut with a diamond saw or established with cold milling equipment. It is usually only required when manual techniques of material removal are employed. Figure 7 illustrates a hole that has been extended to sound pavement and firm supporting material. It is suggested that the depth of the patch be 50 percent thicker than the thickness of the failed layer.
- Remove water and debris from the hole. Depending on the size of the pothole, this may be accomplished manually with a pick and shovel or with various combinations of power equipment, i.e., a pneumatic hammer and shovel, backhoe, or font-end loader. Cold milling equipment can also be very effective for this operation.
- Apply a tack coat of asphalt emulsion to the sides and bottom of the hole at a rate of approximately 0.2 gal/yd^2 (1 liter/m^2) using a slow or rapid setting emulsion. The tack coat should either be sprayed or brushed on the edges of the repair, never poured. Figure 8 illustrates the tack coat application.
- Place the patch material in the hole. If the patch is placed manually, use a shovel (not a rake) to place the HMA material taking care to avoid segregation. The hole should be overfilled by 20 to 25 percent of its depth to provide adequate material for compaction. An asphalt rake should be used to feather or blend the patch edges.
- Compact the patch material with a hand device or a small vibratory, roller. It is preferable to use compaction equipment whose surface is smaller than the size of the patch. It is very difficult to achieve satisfactory compaction with equipment that bridges the repair area. Figure 9 illustrates the compaction of the patch material.
- The patch should be compacted thoroughly using proper equipment. For additional compaction by traffic and to help prevent standing water from accumulating in the patch area, the finished patch should have a 0.1 to 0.2" (3 to 6 mm) crown, as illustrated in Figure 10.
- The edges of the patched area should be sealed with crack sealant. For areas with significant amount of rainfall, the entire patch should be fog sealed.

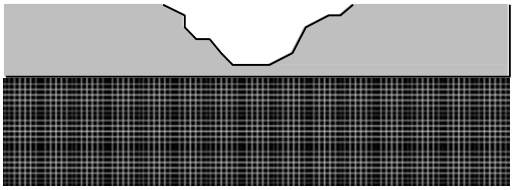

Figure 6. Pothole Area

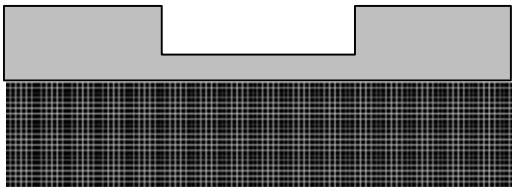

Figure 7. Surface and Base of Pothole Prepared for Treatment

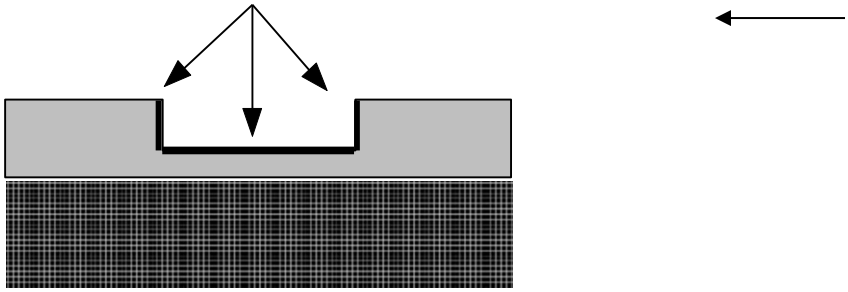

Figure 8. Tack Coat Applied to All Sides of Hole

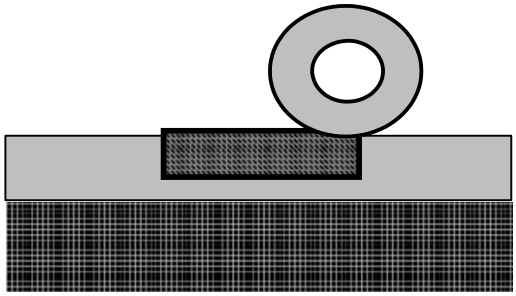

Figure 9. Patch Material Placed and Compaction in Progress

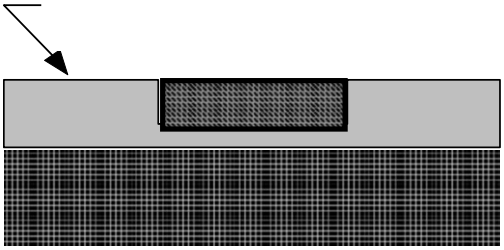

Figure 10. Finished Patch with a 0.1 to 0.2" (3 to 6 mm) Crown

Injection Patching

Injection patching is a rapid and effective method of patching that requires specialized equipment. This method is used for roads with lower traffic volumes and is an alternative to the throw and roll method. These patches are temporary, but generally have a longer life than throw and roll patches (FHWA, 1999). The steps for injection patching are described below:

- Prepare the site for patching by blowing debris and water from the hole with the application nozzle
- Spray a tack coat of emulsion on the sides and bottom of the hole at a rate of approximately 0.2 gal/yd^2 (1 liter/m^2)
- Blow asphalt/aggregate mixture into the hole, filling the hole to the top.

General checklist and precautions:

- Surfaces where a tack coat is to be applied should be free of water, foreign material, or dust

- Patching should not be done when temperatures are below 40°F or during unstable weather
- No greater amount of patching asphalt should be planned in one day than can be properly distributed and rolled during that day
- Specified thickness of each course should not exceed 4" without applying uniform compaction
- During spreading and leveling of the patch material, care should be used to prevent separation of aggregates and fines due to over handling
- All asphalt patches should be compacted thoroughly, whenever possible by rolling. When not possible to use rollers, the use of power tampers or vibratory plates might be an acceptable alternative
- All compaction should be commenced at the lower edge and gradually be advanced evenly to the crown or match with existing pavement
- Rolling operations should avoid jerky, stopping or starting on the repair or excessive speeds
- Petroleum products (diesel, gasoline, etc.) should not be allowed to come into contact with the repair
- All loose aggregate should be swept off the roadway.

5.3 Traffic Loop Maintenance

NOTE: **Consult your Regional Coordinator or engineer for specific installation requirements that can/will be applied following the installation of any type of traffic control device.**

An inductive loop is simply a coil of wire embedded in the road's surface. To install the loop, asphalt is placed first. Then, the loop pattern is cut with a saw, the loop placed, and the cuts are sealed as cracks would be. The wire is placed in the groove and sealed with a rubbery compound.

5.3.1 Traffic Loop Maintenance

Installation of metal detection loops has increased significantly in the last 20 years. In addition to new installations, loops destroyed by sewer construction, street paving, and expansion of utility networks are continually being replaced.

Maintenance for traffic loops is specific to the type of inductive loop used. If pavement is to be milled where traffic loops have been installed, as-built plans should be reviewed to determine the depth of any loops embedment. This allows the maintenance team to keep the milling operation above the loops, where possible.

In general, removal of traffic loops will automatically happen when roads are milled, so separate specifications addressing the removal are not usually necessary. For replacement, construction crews will simply saw cut grooves for loop placement into the new pavement.

6 SURFACE MAINTENANCE – GRAVEL

Ideally, roads are constructed above the natural ground to provide efficient and adequate drainage. The goal for non-paved roads is to provide a smooth, firm, tractionable, and maintainable surface, with minimal washboarding or potholing. The surface course should be maintained to a uniform thickness of not less than 2". Materials appropriate to be applied as a surface course should be crushed, granular material meeting the gradation requirements of the local state Department of Transportation, or the current edition of the FHWA standard specifications (FP-03 Table 703-3, as of this writing) Surface materials should be free of organic matter, high proportions of clays or silts, or other deleterious matter.

Surface aggregate maintenance or repair should occur whenever irregularities, washboarding or potholing become objectionable from a serviceability perspective, or become prominent, widespread, or increasing in magnitude/extent.

6.1 Understanding Road Cross Section

Figure 6.1 shows a typical cross section of a gravel road. If states have minimum standards or policies for low-volume roads, they may be used as a guide if compatible with local park policies and practices.

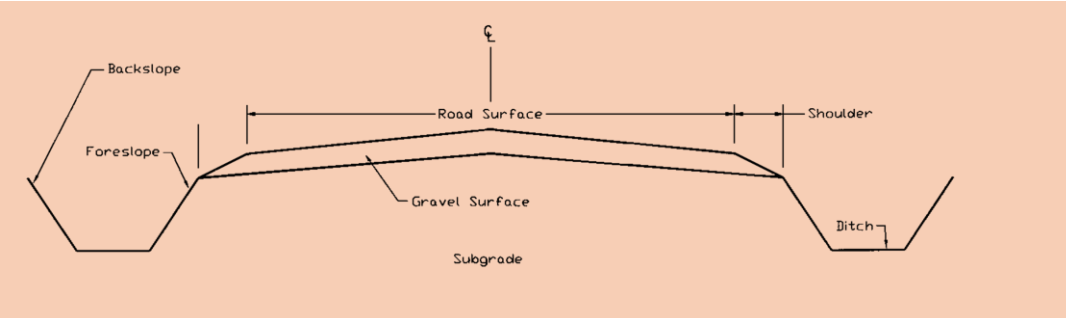

Figure 11. Components of the Roadway Cross Section

In order to maintain a gravel road properly, operators must clearly understand the importance of three basic elements:

1. A crowned or super elevated driving surface,
2. A shoulder area that slopes away from the edge of the driving surface
3. A ditch on the cut-side of the roadway.

The shoulder area and the ditch of many gravel roads may be minimal. This is particularly true in regions with restricted roadway footprints (due to topographic constraints or local policies). Regardless of the limitations in a given location, the basic elements noted above are critical to the long-term performance of the road. Keeping the crown, super elevation, foreslope, and ditch established and shaped correctly is a key maintenance responsibility. Standing water at any place within the cross section (including the ditch) is one of the major reasons for distress and failure of a gravel road.

6.2 Crowning and Super Elevation

Road crowning and super elevating are the primary means by which surface water is drained off the road surface. To crown a road means to create a high point that runs lengthwise along the center of the road. Either side of this high point is sloped gently away from the center toward the outer edge of the road. To super elevate a road means to tilt the entire road surface in one direction so that water from the entire width of the road flows off as sheet flow to the side of the road.

Problems develop quickly when a gravel road does not drain efficiently. Water will collect on the road surface during a rain and will soften the surface. This will lead to rutting, which can become severe if the sub-grade also begins to soften. Even if the sub-grade remains firm, with a weakened surface traffic will quickly create smaller depressions in the road where water collects and the road will eventually develop potholes. A properly drained gravel road should have the proper crown or super elevation. It is possible to have too much crown or super elevation, as it creates an unsafe driving condition. This is especially of concern in regions where snow and ice may be encountered on the roadway.

Crown or super elevation should be a function of road geometry and design speed. It typically varies between a minimum of 2 percent and a maximum of 8 percent. Before or when changing the cross-slope of a road, consult with the FHWA, the Denver Service Center, or your local park engineer to be sure the correct slope is achieved for the conditions.

Crown and super elevation can be measured or constructed using very simple tools, from string-lines and hand levels to crown gauges and sophisticated electronic slope controls for graders. Whatever the tool, it is good to know not only what the existing cross-slope is, but what it should be for a particular roadway.

There is one common problem with crown that needs to be considered. The ideal shape is a straight line from the shoulder to the centerline of the road. However, this section can sometimes become rounded. The engineering term for this is “parabolic crown.” This is a problem. The middle portion of the lane will have considerably less crown than the outer edges. Water may not drain efficiently, causing potholes and ruts. The most likely cause of parabolic crown is excess wear at the center of the grader blade’s cutting edge. This is normal wear and will vary with types of gravel, width of road, wheel path location, and other factors.

A good operator will make an effort to avoid the parabolic shape on a roadway by keeping the cutting edge straight. This can be accomplished through a variety of methods. One is to use a cutting torch to straighten the cutting edge whenever 1/2 to 3/4" or more of center wear exists. Another method is to use a thicker, harder section of cutting edge in the middle of the moldboard to resist wear. This will retard center wear but generally will not eliminate it. Another option is to use the modern carbide-tipped bits on the cutting edge. These are extremely wear-resistant and dramatically reduce center wear. There are also carbide insert or carbide-faced cutting edges that are very wear-resistant.

6.3 Roadway Grading

Grading is the process of smoothing and re-establishing crown or super elevating for a non-paved road. This practice involves using a grader with a steel cutting blade or tines to redistribute

soil material. The grader is the most frequently used piece of equipment for general roadway maintenance. It can be very effective when used by an experienced operator.

Regular grading is also an effective means of redistributing the small windrows of road material that may have been washed to the road edge or pushed to the edge by traffic. These windrows will interfere with normal drainage by collecting water before it can drain off the road and channeling it along the shoulder or edge of the roadway. This may cause damage to the edges or road shoulders during periods of heavy rain.

6.4 Road Shoulder

The road shoulder serves several essential functions. It is there to support the edge of the traveled portion of the roadway, to provide a safety area for errant drivers to regain control of vehicles, to provide room for disabled vehicles, and to carry water further away from the road surface to the embankment slope or ditch line.

6.5 Surface Maintenance

Scarifying or rough grading to correct surface irregularities should be performed across the entire roadway width in the area to be worked. After rough grading and/or scarifying has been completed, the loosened material should be worked to a uniformly sized condition and all rock larger than the material appropriate to be applied as a surface course should be removed if possible. Whenever possible, the moisture content will be brought to the optimum level by the addition of water or by the drying of existing material. Laydown of properly sized material shall proceed until all material has been graded to a uniform cross-section and width. The width after this maintenance operation should conform to the originally designed road width.

6.6 Types of Gravel

This section will discuss the most common types of material to be used for gravel roads. They are quarry aggregates, such as limestone, quartzite and granite; glacial deposits of stone, sand, silt, and clay; and river run gravels that generally are a mix of stone and sand. It is recommended to use the best quality crushed material locally available.

There are two major differences between surface course and base course materials. Good gravel for base courses will generally have larger maximum-sized stone and a very small percentage of clay and/or fine material. This is necessary for the strength and good drainage needed in base gravels. This material will not bind together well and will ravel under normal traffic volumes. It will be difficult to maintain. A good surface course material will have angular (crushed) stone with sufficient fines and plasticity to bind together but not so much as to act as a clay-like surface. Again, see the current FHWA specifications (FP) section 703 for acceptable surface course gradations and plasticity.

6.7 Gravel Gradation

Gravel is a mixture of three sizes or types of material: stone, sand, and fines. Without a good blend of these three sizes, the gravel will perform poorly. Unfortunately, poor performing gravel will often be blamed on the maintenance operator, but the operator cannot make good gravel out of bad gravel. Bad or poorly graded gravel cannot be changed to good gravel without additional costs, but this extra cost is often well-spent. One common practice for improving surface gravel is to add new, clean, virgin fine gravel. Good surface gravel needs a percentage of stone which gives strength to support loads—particularly in wet weather. It also needs a percentage of sand-

sized particles to fill the voids between the stones and give stability. A percentage of good, plastic fines are also needed to bind the material together, which allows a gravel road to form a durable, resilient surface and shed water. In many regions of the country, this is natural clay, which gives the gravel a strong cohesive characteristic and keeps a reasonably tight surface especially during periods of dry weather.

However, no gravel surface will perform like asphalt pavement. There will be some loose aggregate, or "float", on the surface of virtually all gravel roads. Striving to achieve the highest quality in materials and construction that budgets and local sources allow will improve the performance of a gravel road.

In a few cases, the gravel may simply be screened and/or loaded onto trucks without processing. This is often referred to as "bank run" or "pit run" gravel. There are few natural deposits of material that have an ideal gradation without being processed. In some areas of the country, it is still common to process gravel simply by screening to a maximum top size. However, a great benefit is gained from processing the material by crushing. This means that a good percentage of the stone will be fractured in the crushing process. The broken stones will embed into the surface of a gravel road much better than rounded, natural-shaped stone. It also means that the material resists movement under loads better and gives better strength or stability. This will vary throughout the country, but bank run gravels are nearly always improved through the crushing process. Quarry gravels are considered very good material since they are composed of virtually all fractured particles.

As more of our asphalt pavements wear out, many of them are recycled. This is usually done by milling or crushing. Sometimes the material is available for use on a gravel road. It can be a good surface, but there are also pitfalls. In this material, the bituminous portion of the old pavement becomes the binder. When placed on a road in hot weather, the recycled asphalt can take on the characteristic of pavement, but it will be a weak pavement. It will often develop potholes and will be hard to maintain with simple blade maintenance. To help overcome this problem, the material should be placed at a minimum 3" compacted depth and only on a road that has a strong sub-grade. A better option is to mix 50 percent recycled asphalt with 50 percent virgin gravel. This will generally provide a material that still has a good binding characteristic but remains workable for maintenance and reshaping. Performance is good when recycled asphalt is mixed with crushed, recycled concrete.

6.8 Aggregate Placement

Imported aggregates should be delivered to the roadbed as uniform mixtures and each layer should be spread in one operation. Segregation should be avoided, and material should be free from pockets of coarse or fine materials, clay, silts, or other deleterious matter. Delivered aggregate should be brought to optimal moisture content by the same means as described in Section 6.5.

6.9 Compacting

Compaction will be achieved using rollers of sufficient size and compactive ability (suggest at least 8 ton gross vehicle weight with vibratory capacity). Rolling should begin along the edge of the area to be compacted and should gradually advance toward the centerline. Rollers should be operated along lines parallel or concentric to the centerline. The relative compaction of each lift should meet or exceed 95 percent of American Association of State Highway and Transportation

Officials (AASHTO) T-180. If it is not practicable to use density gauges or to run the AASHTO T180, the following guidelines may be acceptable: for an initial lift of 2", a minimum of three passes should be applied.

For each additional lift of 2", increase the number of roller passes by one per lift. Lap each pass one third of the roller width. Operate the roller at speeds between 1.5 and 3 mph.

6.10 Dust Control

The goal for dust control is to protect roadside resources (vegetation, soils, and water) from damage due to excessive dust migration and deposition; to protect the road surface from the excessive loss of fine materials; to reduce or eliminate unsafe driving conditions due to lowered visibility; and to provide the public and the wildlife protection from air quality related health hazards.

6.11 Equipment

The primary focus of this section will be the use of the motor grader for gravel road maintenance. However, there are other devices used for the job that can work well. Front or rear mounted grading attachments for tractors, road rakes, and other devices of various designs are used in some areas of the country; however, the basic principles of shaping are the same.

Operating speed in blading operations must not be excessive. It is difficult to do good work above a speed of 3 to 5 mph. When the machine begins to “lope” or bounce, it will cut depressions and leave ridges in the road surface.

It is important to keep the angle of the moldboard somewhere between 30 and 45°. It is a challenge to recover loose aggregate from the shoulder of the roadway without spilling material around the leading edge (toe) of the moldboard. Operating without enough angle is a primary cause of this spilling.

Along with correct angle, it is important to understand proper pitch or “tilt” of a moldboard. If the moldboard is pitched back too far, the material will tend to build up in front of the moldboard and will not fall forward and move along to the discharge end of the blade. This causes excess material loss from the toe of the moldboard. It also reduces the mixing action that is desirable when recovering material from the shoulder and moving it across the roadway, leveling and smoothing it in the process. This mixing action is part of routine maintenance. Traffic tends to loosen material from the road surface and displace it to the shoulder area as well as between the wheel tracks. The stone will tend to separate from the sand and the fine sized material. At the same time, small potholes and an uneven surface will develop. It is the job of the maintenance operator to recover the material; mix it again as it rolls along the face of the moldboard; and restore good surface shape, texture, and compaction.

7 CHECKLISTS

INSPECTION AND MAINTENANCE SCHEDULE

Road maintenance is an ongoing task. Regularly checking on and repairing any issues found is vital to maintaining a good road. The following schedule can be used as a guide for creating your own inspection and maintenance checklist.

Table 2. Inspection and Maintenance Schedule

	In the SPRING	In the FALL	After Every MAJOR STORM	Inspection Date & Condition
ROADWAYS				
Grade and crown/super elevate the road surface and shoulder (year round roads should be graded and crowned 4 times per year—spring, twice in summer, and fall)	X	X		
Clear accumulated winter sand along the roadway and remove false berms	X			
DITCHES				
Inspect ditches and swales	X	X	X	
Remove any obstruction and accumulated sediments, leaves, or debris	X	X	X	
Stabilize any erosion	X	X	X	
CULVERTS				
Remove accumulated sediment, leaves, and debris at the inlet, at the outlet, and within the culvert	X	X	X	
Repair any erosion damage at the culvert's inlet and outlet	X	X	X	
VEGETATED SLOPES				
Inspect all slopes and embankments	X		X	
Replant bare areas or areas with sparse growth	X		X	
If you find areas with erosion, armor the area or divert erosive flows to areas that can withstand concentrated flows	X		X	

8 RESOURCE DIRECTORY

Denali National Park and Preserve, 2005, Routine Maintenance, Repair and Operating Standards, March 2005.

Federal Highway Administration, FP2, Crack Seal Application, Pavement Preservation Checklist Series, November 2001.

Federal Highway Administration, FP2, 1 Crack Seal Application, Pavement Preservation Checklist Series, November 2001.

Federal Highway Administration, FP2, 2 Chip Seal Application, Pavement Preservation Checklist Series, September 2002.

Federal Highway Administration, FP2, 3 Thin Hot-Mix Asphalt Overlay, Pavement Preservation Checklist Series, September 2002.

Local Technical Assistance Program, Distress Identification Guide from the Long-Term Pavement Performance Program, Asphalt Concrete Pavements, August 2005.

Caltrans Division of Maintenance, MTAG Volume 1 Flexible Pavement Preservation 2nd Edition, Chapter 7 Chip Seals, October 30, 2007.

Montana Department of Transportation, MTDOT Maintenance Manual, December 20, 2009.

Michigan Department of Transportation, Maintenance Performance Guide, November 2005.

Michigan Department of Transportation, Surface Maintenance, Maintenance Performance Guide, October 2008.

U.S. Environmental Protection Agency, Gravel Roads: Maintenance and Design Manual, 6 March 2012.

Federal Specification TT-P-1952 Paint, Traffic Markings, Pavement Markings Specification Item, p. 620.

Pavement Edge & Vehicle Stability—A Basis for Maintenance Guidelines by Zinner and Ivey 1982.

American Association of State Highway and Transportation Officials (AASHTO), "The Roadside Design Guide", 1989, 1996, 2001.